SURFACE PLASMON RESONANCE STUDY OF SINGLE-WALLED NANOTUBE POLYMER FILM

V.I. Chegel,

Lashkarev Institute of Physics of Semiconductors of NASU, pr. Nauki, 41, 03028, Kyiv, Ukraine

L.V. Poperenko, Y.V.Chegel , V.V. Pokropivny*,

Physics Department, T. Shevchenko National Kyiv University, 6 Acad. Glushkov Ave., 03022 Kyiv, Ukraine

*Frantsevich Institute for Problem of Material Science of NASU, 03142 Kyiv

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Abstract

Surface plasmon resonance (SPR) in a first time was applied to experimental study and modeling of the single walled nanotubes (SWNT)-polymer films. Several types of SWNT, including carbon and bornitride shows unexpected optical properties for matrix film consisting of nananotubes and polyethilenimine, placed on the surface of evaporated SPR-supported gold film. Modelling of obtained reflectance dependencies, using Fresnel reflection coefficients for cases of simple SPR multylayers structure and possible waveguide was performed. Another possible explanations of observed phenomena are discussed..

Introduction

Surface plasmon resonance (SPR) method is power tool for real-time study of a optical properties and geometry of nanofilms and intensively applied into practice [1-2]. Single walled nanotube (SWNT) have been the subject of extensive investigations last years [3-4] due to they unique mechanical and electronic properties. The basic objective of presented work is a first observation of changes in behaviors of conventional SPR in a gold film covered by single walled nanotube (SWNT)-polyethilenimine layer. The technique of use of SPR assumes an irradiation of the interface between a glass prism, covered by thin (~45nm) gold layer (optically more dense medium) and the researched material (optically less dense medium) from the side of more dense medium by p-polarized laser beam and measurement of the reflected intensity under conditions of attenuated total reflection. The dependence of the intensity of the reflected irradiation vs. an angle of incidence (the surface plasmon resonance-curve) has a minimum at the characteristic angle of incidence, that reveals involving of energy of laser irradiation for oscillation of plasma of free electrons at the surface of gold film (surface plasmon). The form of the SPR-curve and, in particular, the angle position of the minimum, depends on the optical constants and thickness of all substances with which the electromagnetic wave of plasmon cooperates. In presented work we have studied a different types of SWNT- polyethilenimine films, using SPR method. Experiment was carried out with use of SPR-device Biosuplar-2 (www.biosuplarusa.com), where open optical circuit includes the gold film on which nanotubes in a mix with polymer is represented. The measurements was performed for several types of polymer matrix-SWNT nanotubes, placed on an surface of Au film by dropping. The samples of nanotubes were differed between itself with concentration of nanotubes. To compare the results, pure polymer films and film for polymer, mixed with soot was measured also.

Result and discussion

For all SWNT containing samples as well as for bare Au angular reflection spectra for air conditions were measured (Fig.1). It is seen, that surface plasmon resonance is observed on all samples, containing SWNT and on a bare gold. The resonant minimum for the comparison sample (pure polymer) as well as for sample with soot was not observed. This result is surprising, because of strong dependence of SPR angular position on mass of material, involved in electric field of surface plasmon. It was noted also, that depth of SPR minimum directly depend on the homogeneity of film and increase with more dense packing of nanotube layer. With another words, we observe a trend, that is not in agreement with a classical approach in SPR measurements.

The possible explanations of the observed phenomena will be discussed. An appearance of reflective dipping with such angular position in presence of high refractive layer on the surface of metal is possible, if consider the layer SWNT-polymer, as waveguide. In previews work [5] we show, using Fresnel modeling, that for SPR structures it is possible, when thickness of waveguide exceed 640 nm. AFM measurements shows the thickness of

pure polymer layer, close to 2 μm, that is quite enough for occurring of waveguide modes, if refractive index of layer is close to n=2.2+0.2i. To obtain the effective value of the refraction index of a layer of a polymeric matrix with nanotubes modeling with use of calculation of integrated Fresnel coefficient of the reflection for the system of investigated layers was carried out. The experimental SPR curves were mathematically treated, using procedure of fitting with theoretical SPR-curve. A minimal value of objective function at the end of processing reveals the optical parameters (refractive index and thickness of investigated layer), that is close to real. Calculation for usual multilayers model was performed also. The modeling without waveguide reveals another explanation of observed phenomena, where refractive index of SWNT polymer matrix on the surface of gold is close to refraction of air. This result could be explain by observed high adsorption activity of SWNT, which do not allows a close contact of polymer molecules to gold surface. We will also discuss the relation between the evanescent wave and possibility for tunneling of electrons from nanotubes to surface of gold.

The observed phenomena of nanotube-induced angular shift of SPR opens a new possibility for the revealing of nanotube fractions existing in material as well as to real-time registration of nanotubes interactions with another objects of study, including biological.

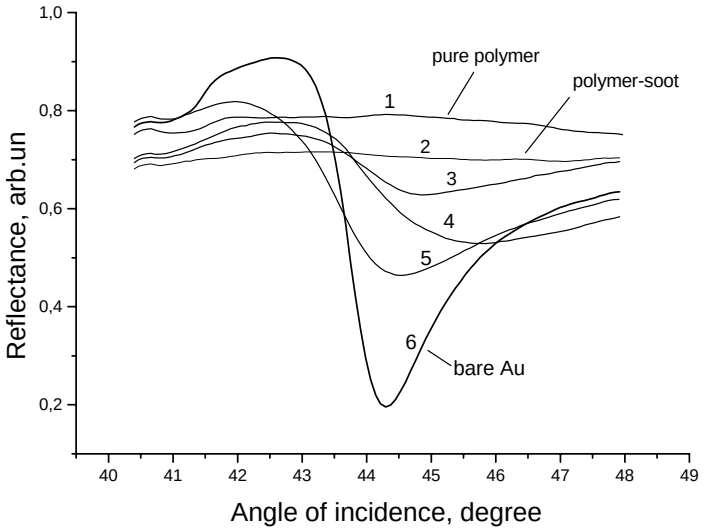

Figure 1. Surface plasmon resonance curves for gold film with different covering. 1 - pure polymer film, 2 - matrix polymer-soot, 3 - 5 matrix SWNT-polymer (3 - 20% SWNT, 4 - 40% SWNT, 5 –60% SWNT). 6 - bare gold film.

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